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6/9/13
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Illumin Article

Neuroprosthetics Ability to Create Man-made Memories

Neuroprosthetics, mechanical replacements for the human brain, are starting to become a possibility with the advancement of man's understanding of the coding behind the human mind. By interpreting how the brain transmits signals to the human body from a mathematical, physical, and chemical standpoint, scientists are able to map these electronic signals and reproduce them with an artificial prosthesis. This technology is only in the developing stages and has very few finished products for human use. Scientists are finding the constraints behind studying such a complex part of the human body and are focusing their efforts on the hippocampus of the brain, which controls memories. Hopefully, further development of these neuroprosthetics will help those plagued with Alzheimer's, stroke, or disrupted neuronal networks.

How Scientists Could Implant Memories

As scientists and engineers, we often found ourselves pushing the limits of nature by creating artificial life. Scientists first began this endeavor by developing technology to enhance and replace human's biological processes. Ever since then man has feared losing his humanity to machinery. The medical term for these misunderstood devices is prosthetics; which are artificial mechanisms used to replace a missing or damaged human body part. Prosthetics are now breaching a new frontier, the brain, a part of human anatomy that is probably the most mysterious based on how little we truly know about its mechanics and function. Theodore Berger, a biomedical engineer and neuroscientist has been working with neuroprosthetics for many years now studying their effect on the development of long term memories located in the hippocampus of the brain as shown in

Figure 1.1. His research has shown that an electronic implant has the possibility to aid the user in forming short term memories into long term memories. To better understand the implications behind implementing a new type of prosthetics, it may be helpful to understand what types of neuroprosthetics has worked in the past so far.

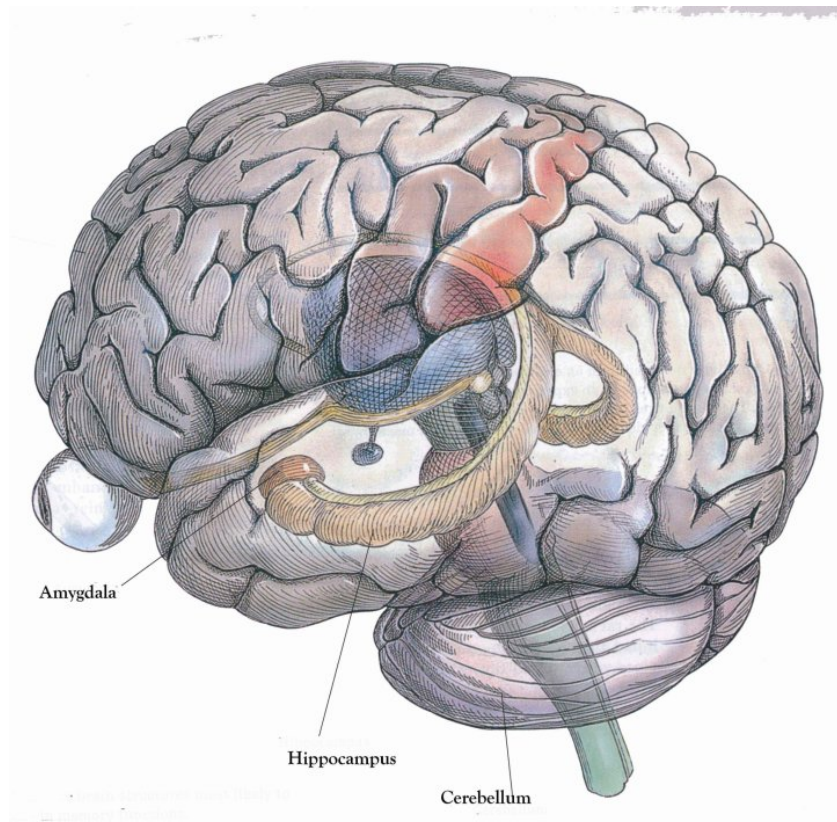


Figure 1.1 [10] *Image of Hippocampus location in the human brain.*

History Behind Neuroprosthetics

The types of prosthetics that relate to this memory implant device the most would have to be those that use electronic signals to stimulate biological functions in the human body. Most of these prosthetics deal with specific senses of the human body. For example for auditory prosthetics, the first know neuroprosthetic was created in 1957 called the cochlear implant. This implant differed greatly from traditional hearing aids that simply

amplify sound for the human ear. “Cochlear implants bypass damaged portions of the ear and directly stimulate the auditory nerve. Signals generated by the implant are sent by way of the auditory nerve to the brain, which recognizes the signals as sound” [2].

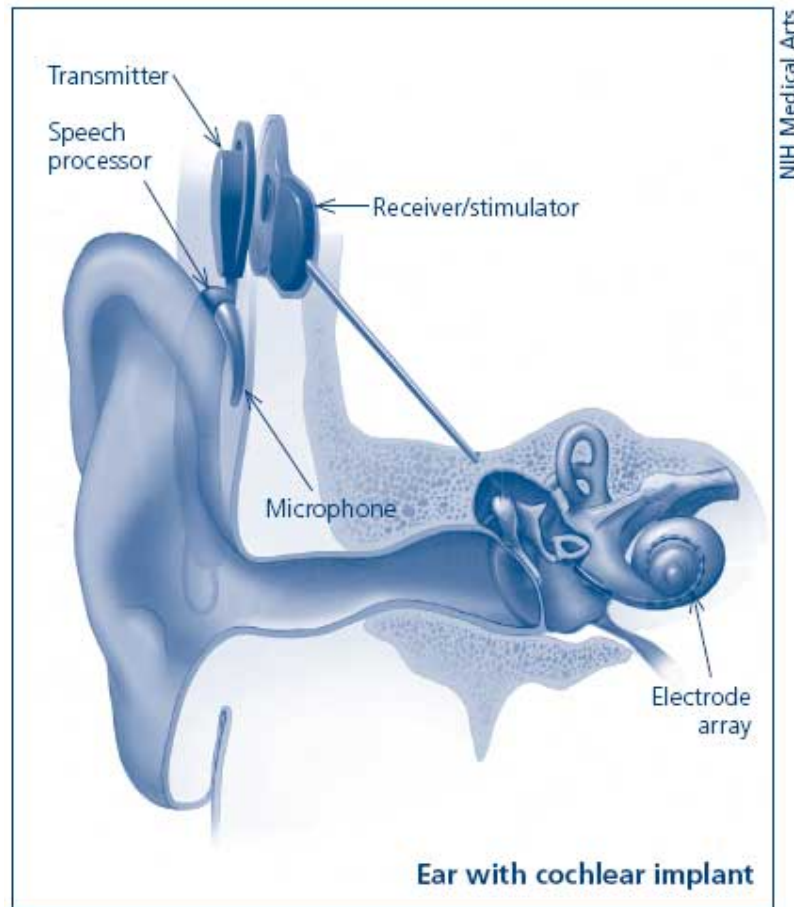


Figure 1.2 [2] *Image of the human ear with a cochlear implant.*

This neuroprosthetic allows a one who is deaf to be able to process different sounds in their environment through means of nervous system making the deaf able to comprehend human speech. From explaining how this invention has enhanced human’s recognition of speech even when missing the sense of hearing, one can understand the progress to be made in neuroprosthetics. Advances in visual and motor neuroprosthetics have been made as well with the invention of artificial retinas for the blind and artificial body parts that

respond to the brain's electrical signals. All of these inventions have yet to directly replace the functions of the brain, but with further study neuroprosthetics will soon surpass that boundary.

Discovery of New Frontier of Memory Reconstruction

Berger himself has been specifically developing silicon chips to allow animals' brains to process information much like a neuron would do. "Restoring a form of cognition" [3] is what Berger compares his work to. His study began with the understanding of the behavior of neurons in regard to the hippocampus part of the brain, which is the part of the brain responsible for forming memory. Berger defines memory as: "A series of electrical pulses over time that are generated by a given number of neurons" [3]. After understanding this key ideal behind how the brain works, one must study the process of the creation of these pulses and how the brains knows when to transmit them based on the subjects interaction with its environment. Through this study of electrical signals, Berger has been able to establish a few mathematical theorems to define how electrical signals move from one neuron to the other within the hippocampus to form long term memories: "Mathematical modeling simplifies the behavior of a system that is experimentally observed over time and space and reveals the consequences of some constraints that are difficult to observe experimentally, for example, the removal of couplings between subsystems" [1, Ch. 7, pg. 129]. What he means by coupling process is the brain's ability to convert energy signals (mechanical, chemical, electromagnetic) emitted from different objects in an environment into electrical impulses as shown on Figure 1.4 [5]. Like any invention, the process relies on experimentation to come up with a reliable product. Berger spends years first

experimenting to understand the hippocampus part brain before he began to create this new form of neuroprosthesis.



Figure 1.3 [3] *Picture of Berger at University of Southern California's biomedical engineering labs.*

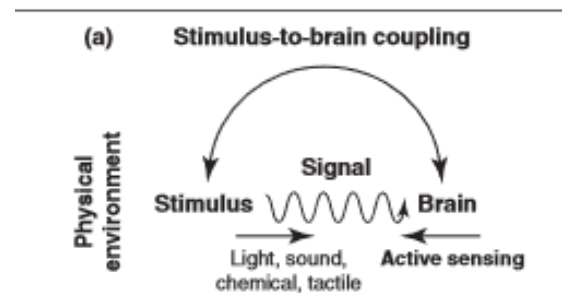


Figure 1.4 [5] *Brain's ability to couple with subsystems*

Development of the Neuroprosthesis

In Berger's earliest work, he analyzed animal's neuron activity when concerning as specific activity involved with memory. For example, he studied how rabbits were conditioned to blink their eyes based on a tone and puff of air by Dr. Richard Thompson at Harvard and in 1976 showed results on how patterns of electrical neuron spikes with respect to time were formed over time in the rabbits brain. Thompson taught Berger the possibilities behind the "study of chemistry of synaptic transmission" [7, Ch. 5, pg. 119]. Berger's studies later were more focused around the code for neurons to send and receive signals leading up to the creation of a long term memory. His results for discover such a code defining it in mathematical terms were: "essentially there is no condition in the brains that is linear meaning you put in 1 and get 2" [3]. In the early 1990s, he began developing

the neuroprosthetic to stimulate memories in animals such as rats, rabbits, and monkeys: “Researchers sent random pulses into the hippocampus and recorded the signals at various locales to see how they were transformed and derived mathematical equations describing those transformations” [3]. The silicon chips’ programs were developed by using this method of study of neuron electrical signals pathway: “This approach is based on the design and fabrication of compact modules containing multiple silicon very-large-scale integrated (VLSI) chips that implement neural like functionality, including dense weighted (synapse-like) interconnections among arrays of neuron-like units” [1, Ch. 12, pg. 295] as shown in figure 1.5). The chip is still under development and has yet to be experimentation, but simpler versions that contain electrodes have been modeled and used in animal test subjects to test the use of mathematically generated electrical codes.

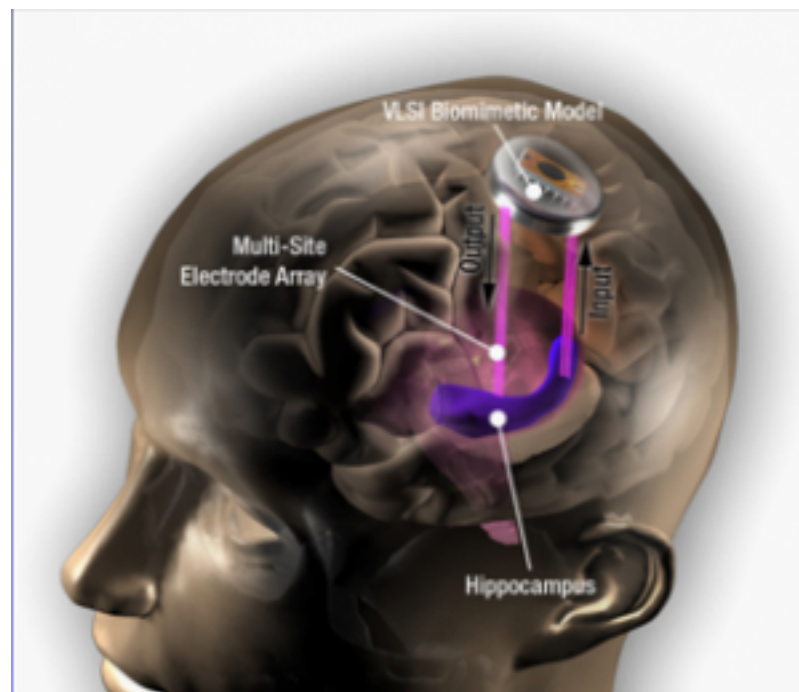


Figure 1.5 [9] *Picture of VLSI Chip implanted into human brain.*

Experimentation with Electrodes in Animal Subjects

Experiments of the neuroprosthetics included testing animals' ability to remember images based on their outcomes such as a rat choosing the right lever to produce a treat. The experiments would make the animal's cognition a variable within the tests. Rats were given drugs to impair their image recognition. Then electrodes were used to help the rats overcome these impairments. Most of the research only studies the brains' signals for certain actions involving memory. None of the experiments involve the implementation of the neuroprosthetic yet. Berger believes that he has only simply studied a few codes for certain memory processes, which are only part of the overall code of the hippocampus' neuron activity: "It is possible that they haven't cracked the code but have merely deciphered a few simple messages" [3]. Furthermore, Berger understands his chips may only help form long-term memories for a limited "amount of situations", but recognizes that his overall goal is to aid those with memory issues.

Ethics Behind Memory-based Neuroprosthetics

The main ethical implication behind this topic of memory implants is the uncertainty that a neuroprosthetic will ever work properly in one's brain. The brain is still a subject of inquiry and the side effects of such devices have yet to be explored. Berger plans to do human studies on "patients with severe epilepsy and using electrodes on the hippocampus to prevent seizures" [3], but that is simply one step in understanding the "memory codes" of the human mind. Technologies like these have a tendency to stay in the prototype phase for years on end simply because scientists want no causalities to obstruct their research and prevent the general public from fearing their work. Questions of ethical implications have always been around ever since man started experimenting with his own anatomy. For

example, the question people often find themselves asking about this field is: Did God (or a higher power) intend for us to change our very being? One might propose that the very idea of evolution proves that it is innate for one to better their chances of survival by any means necessary. In addition, the brain holds key information to allow us to identify ourselves as individuals. If we take that away, what will become of us? Will we become machine (without a soul)? Berger keeps these concerns in mind, when he explains: “Most of us have a sense that there is something sacred about the human and the human brain and it's something not to be touched” [4]. The argument for these new neuroprosthetics lies in their ability to restore neural functions when all other options have failed as well as the ability to control their involvement. Berger’s argument for this new technological breakthrough is: “We are starting to live a longer and so more and more of the diseases of the brain and degenerative or accidental damage to the brain, are going to be seen and must be dealt with” [4]. Berger makes it clear that his work is always cautious in its approach towards altering or repairing the human brain and that his studies are solely for the aid of those who suffer from mental illness. With more breakthroughs in modern technology, humans are becoming more accepting of science's role in the discovery of the mysteries of human anatomy.

The Future of Neuroprosthetics

Whether man accepts machine as progress is the true question to be answered. Memory implants is an interesting topic to begin such a discussion on the alterations of human anatomy with modern technology. Berger’s studies have shown that there is a mathematical explanation to be understood about the coding of the memories in the human

mind. The only question that remains is man's brain meant to comprehend such a code or is it simply too complex for man to understand. With Berger's studies showing how memory can be improved through manual electrical means, how far can we push the limits of the mechanization of the human mind? The brain holds a powerful hold over the survival of the human body and that is mostly the reason people fear tampering with its processes.

Change is something that one's mind does not accept blindly and people fear of losing their sanity is at the top of the list when it comes to modifying one's brain's functions. Time will only tell when humanity is ready to further explore the human's mind and its ability to overcome adversity with technology, but for now neuroprosthetics for internal brain activity will only be studied in theory rather than practice.

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